Effects of Source Field Plate and Pt-gate Metallization on AlGaN/GaN HEMTs Reliability

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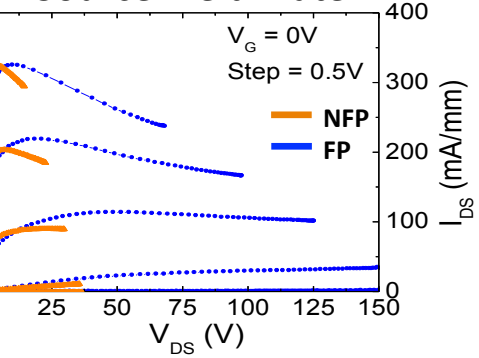
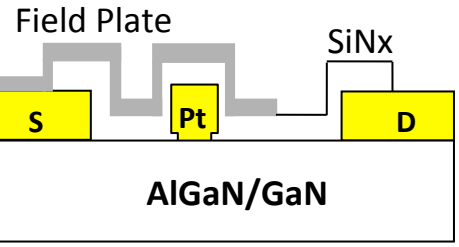
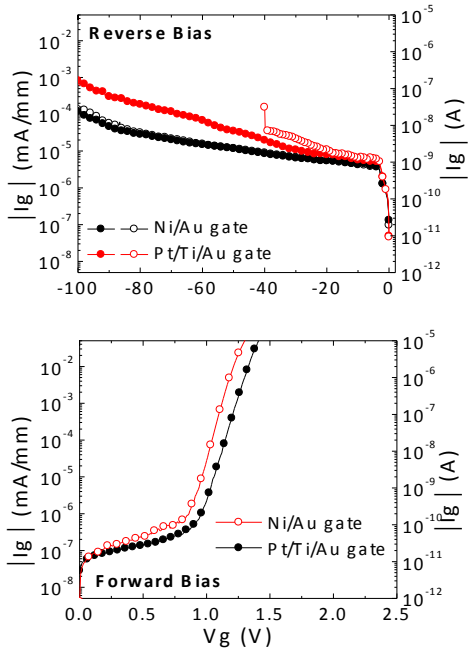
FLOORS

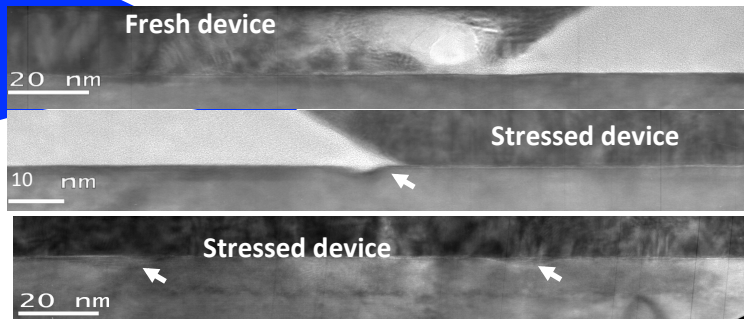
Source-Field Plate HEMT

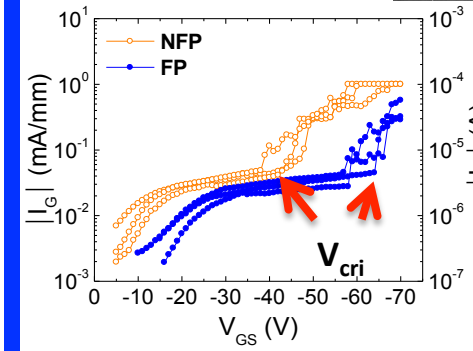


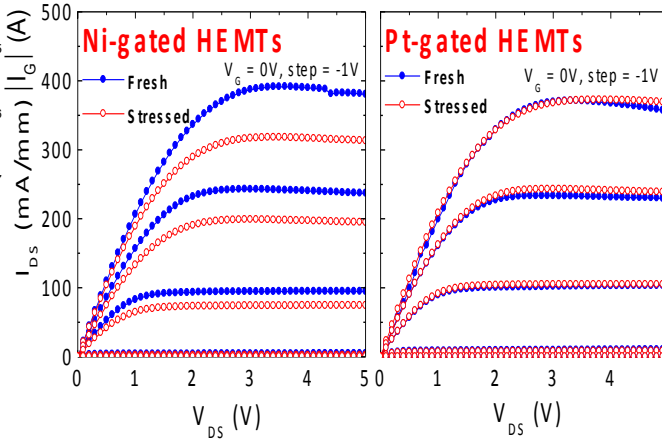


Pt-gated HEMT









t=0, As Built

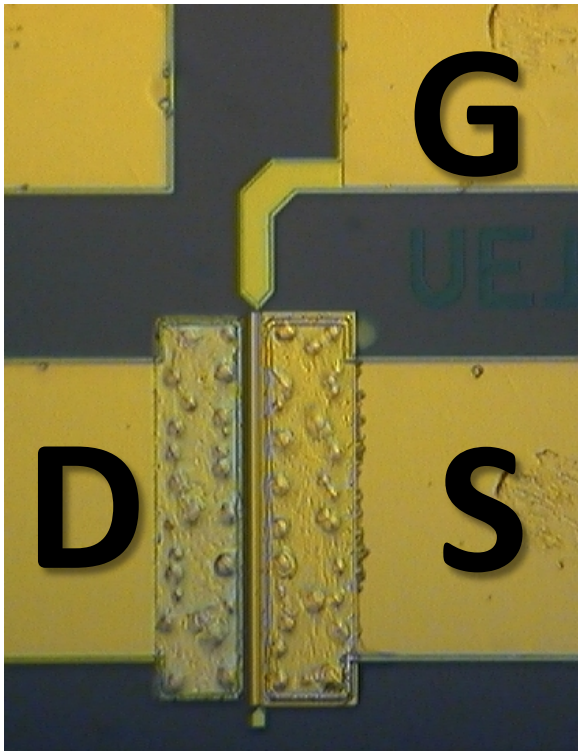
t>0, Degradation

Proposed Degradation Mechanisms

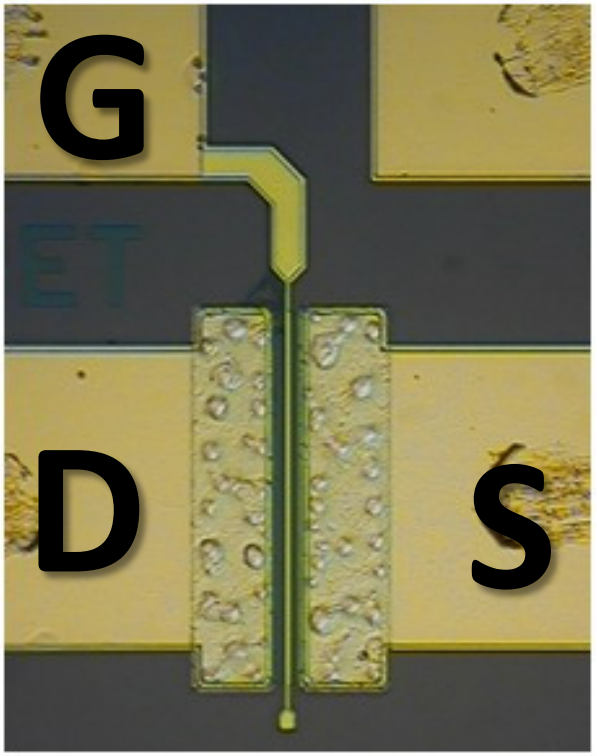
- Hot-electron-induced trap degradation (*Meneghesso, 2008*);
- Crystallographic-defects through the inverse piezoelectric effect (*del Alamo, 2008*);
- Electric-field driven mechanism;
- Gate sinking;
- Ohmic contact degradation (*Meneghesso, 1998*).

Micrographs

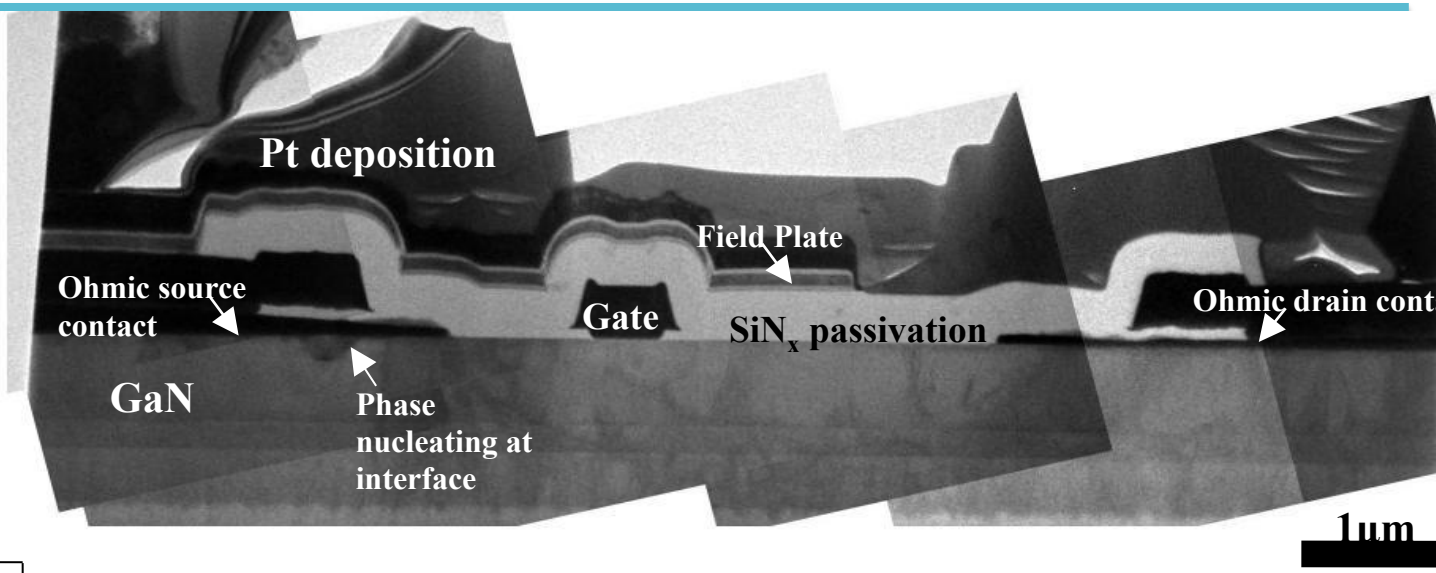
With Field Plate:

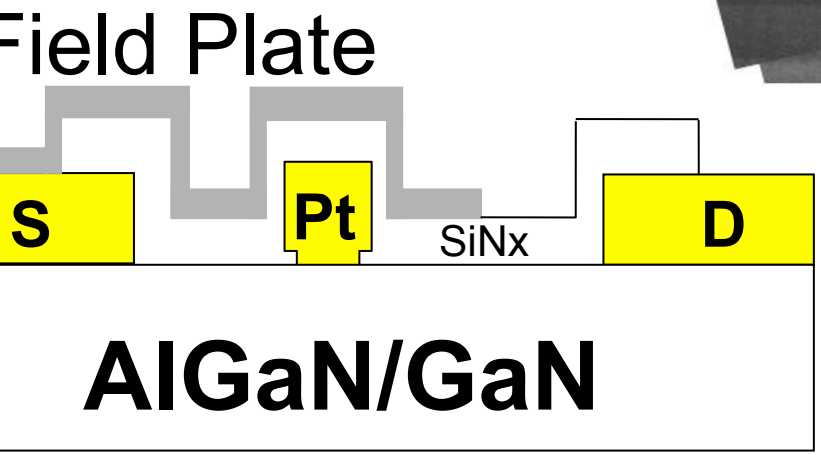


Without Field Plate:

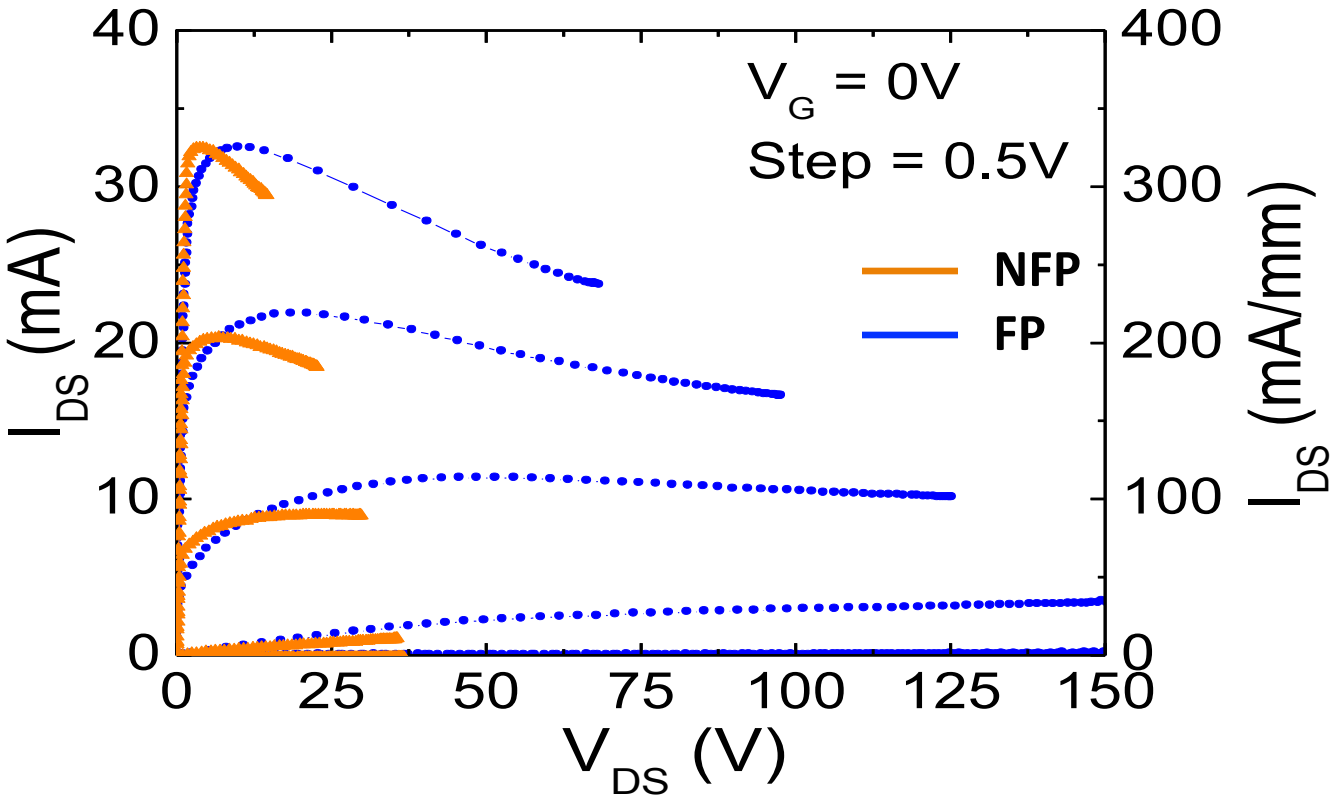


Device Schematic & TEM result

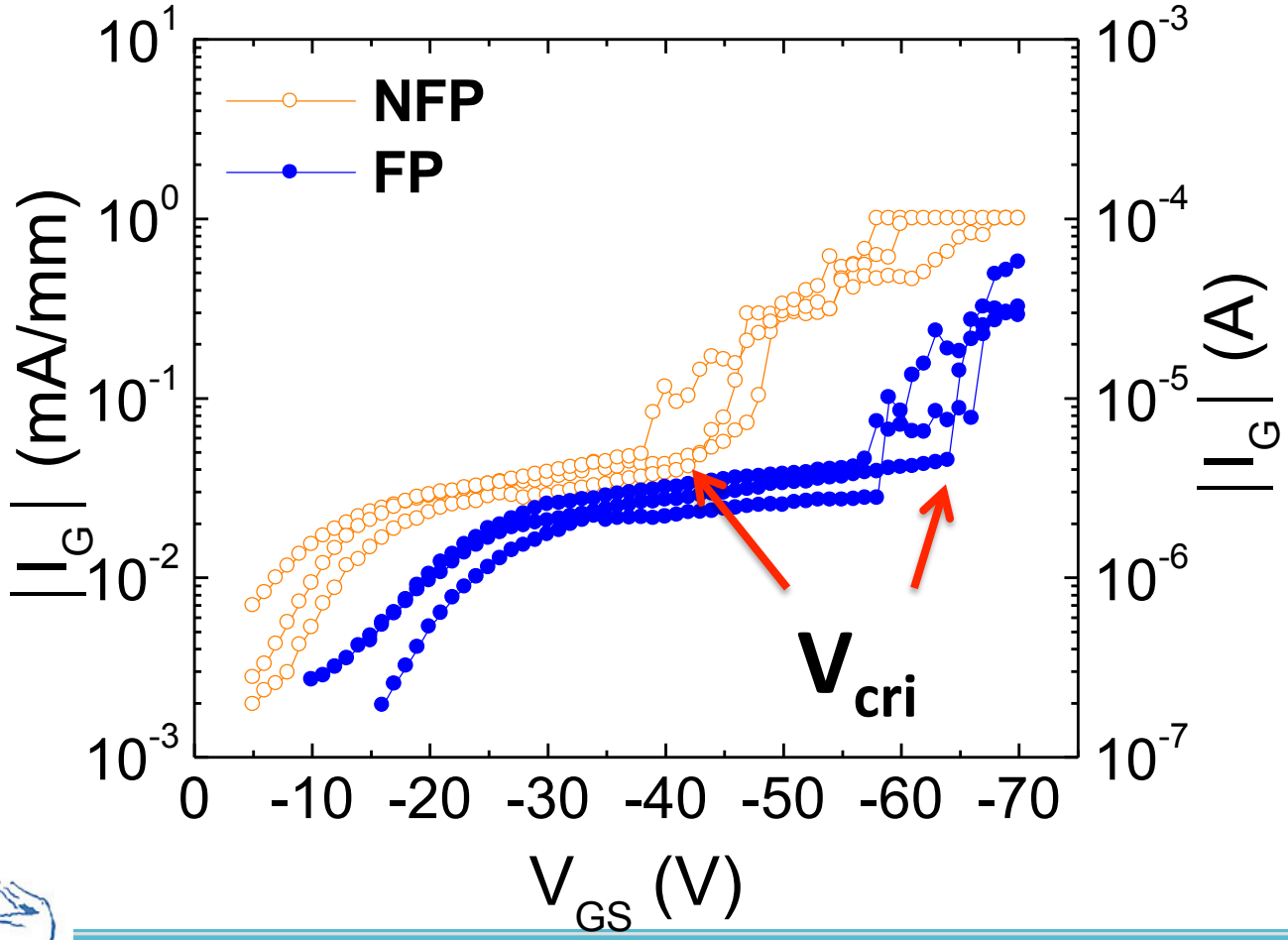




Drain I-V Characteristics



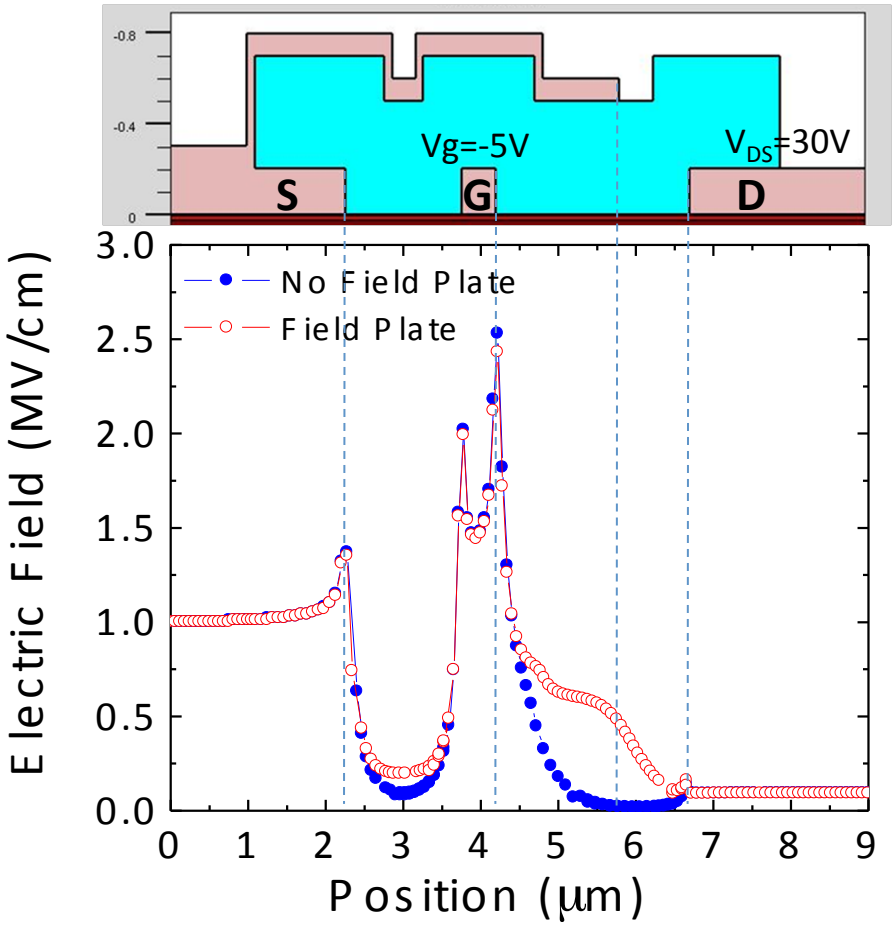
Off-state Stress Result



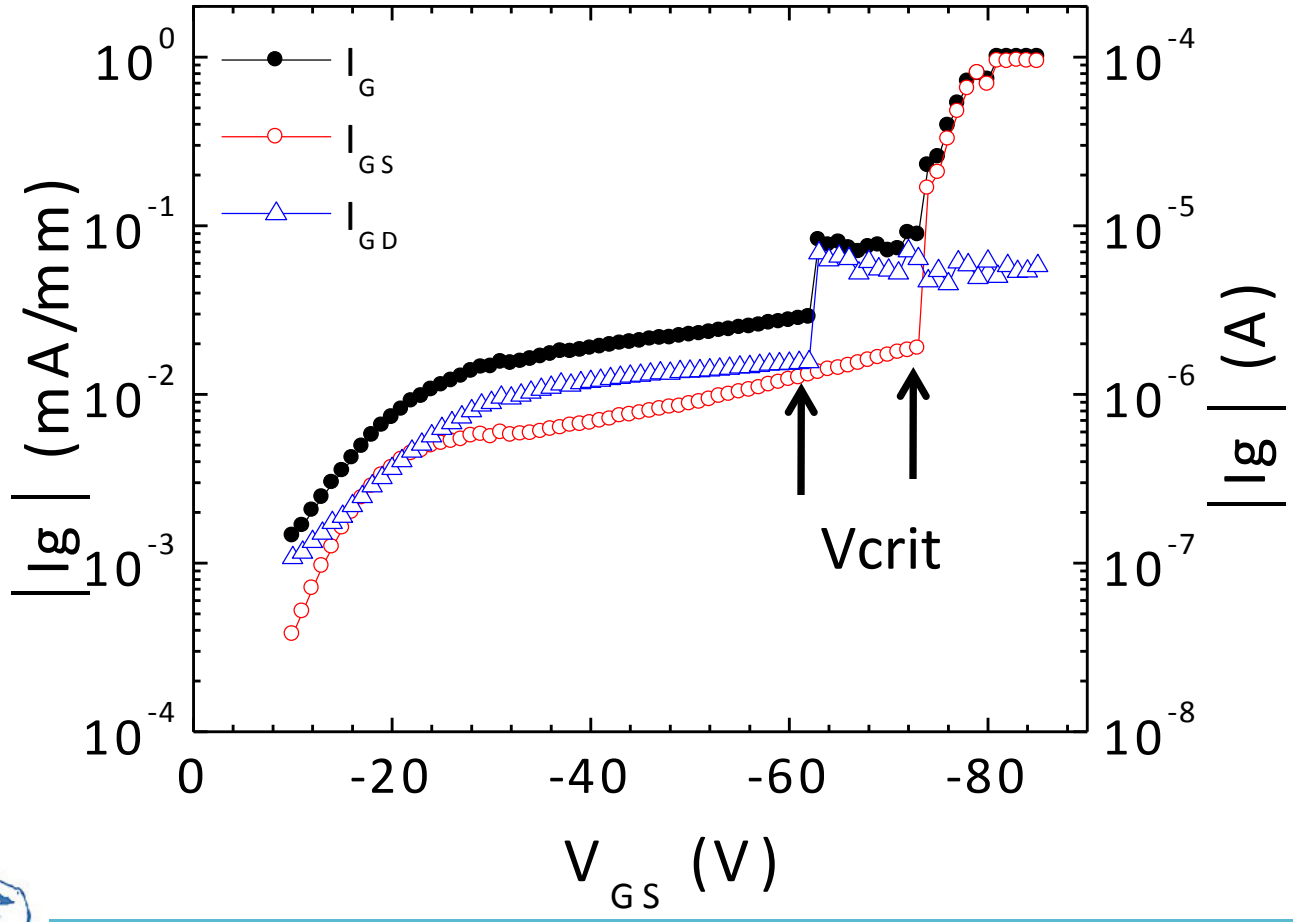
Electric Field Simulation

2-D simulation of the electric field distribution between Source and Drain.

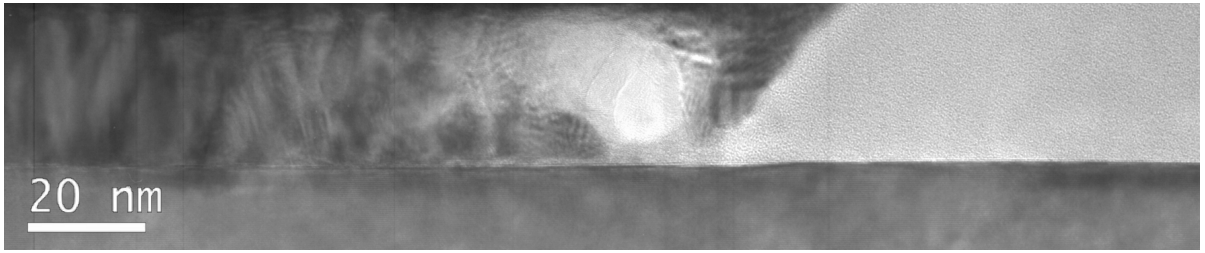
ATLAS/BLAZE
(Automatically tuned linear algebra software)



I_G , I_{GS} and I_{GD} as a function of V_{GS}



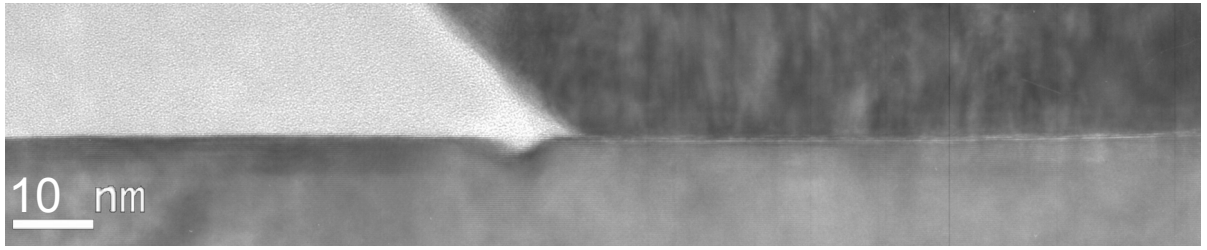
TEM Result



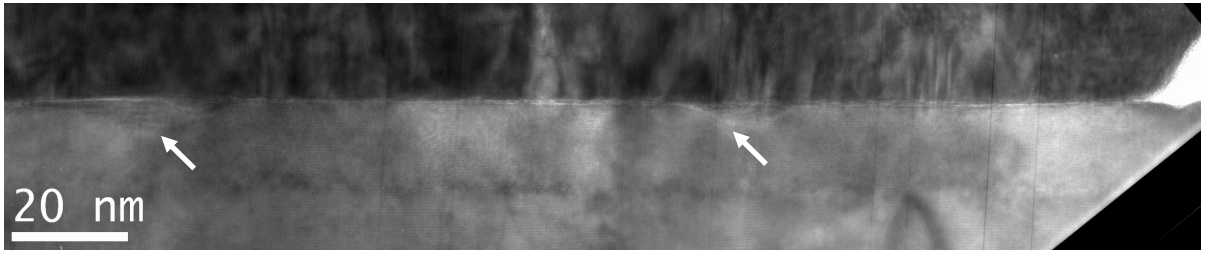
Fresh device

Stressed device

Source side of gate edge

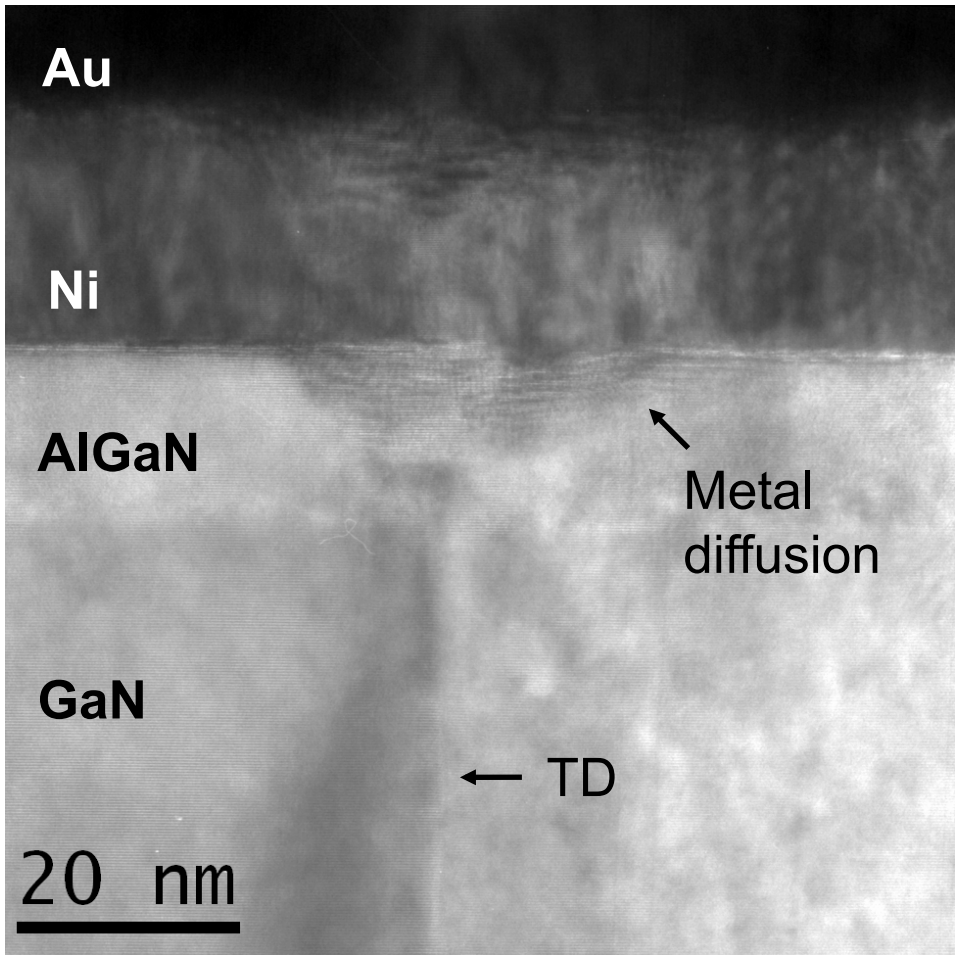


Drain side of gate edge

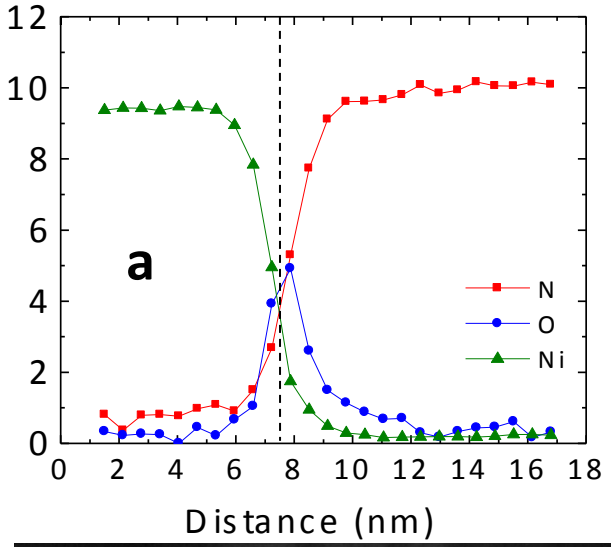


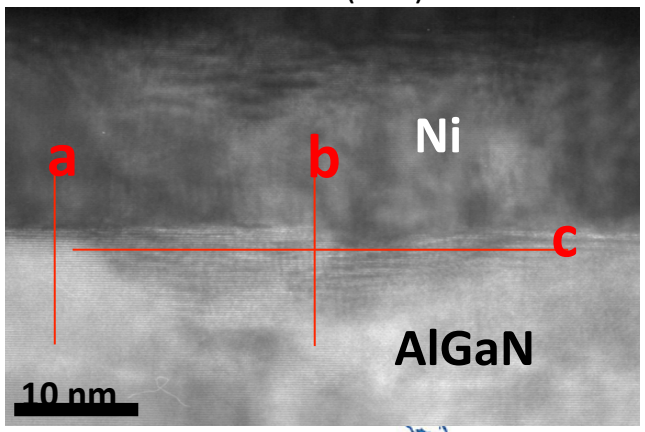
Dr. Smith, ASU

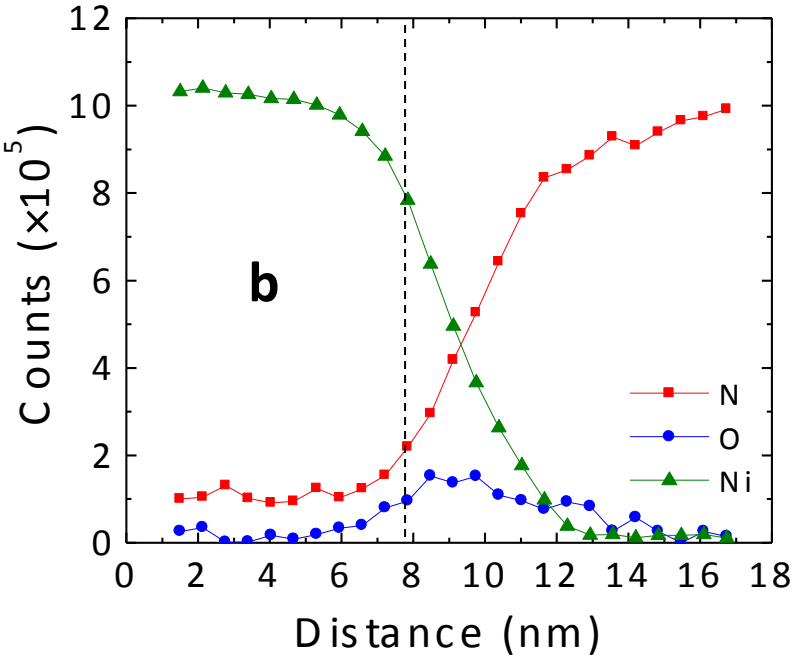
TEM Result

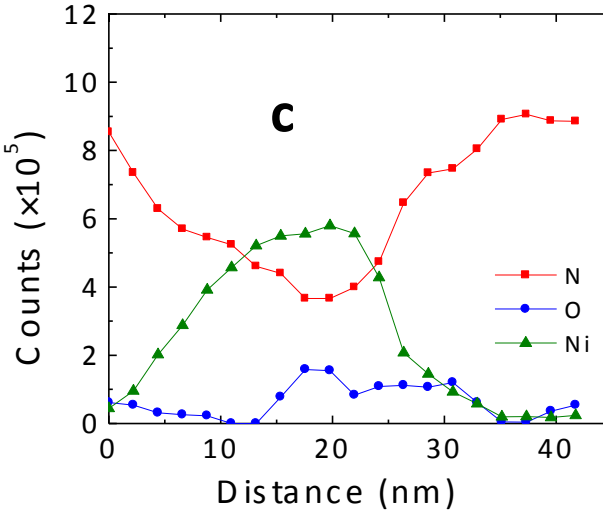


STEM-EELS Line Scan





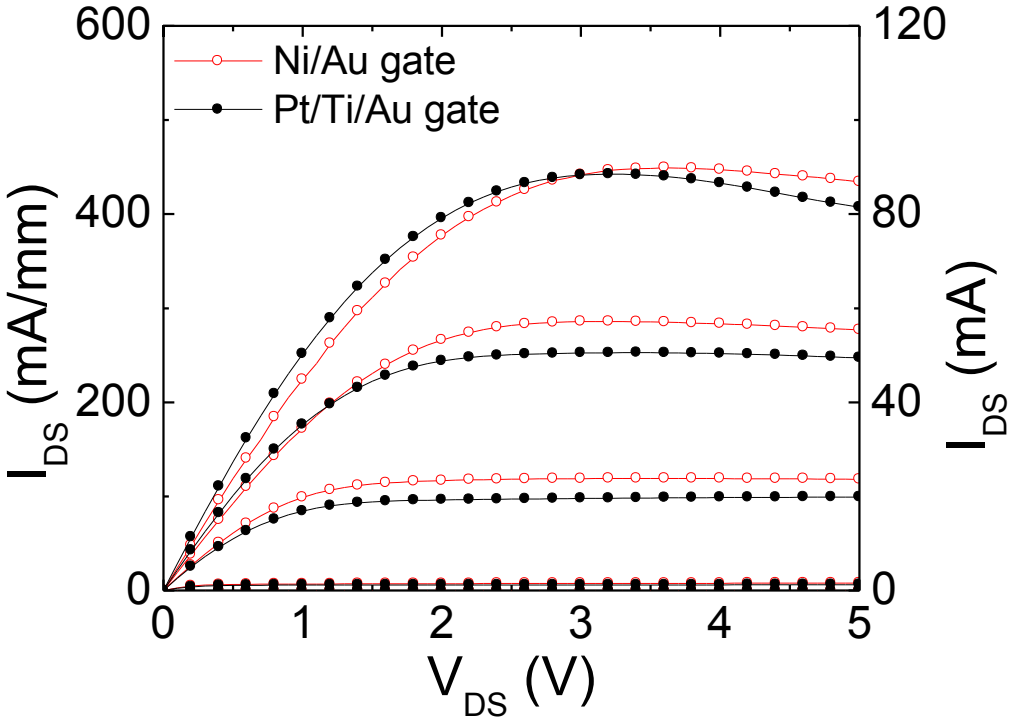


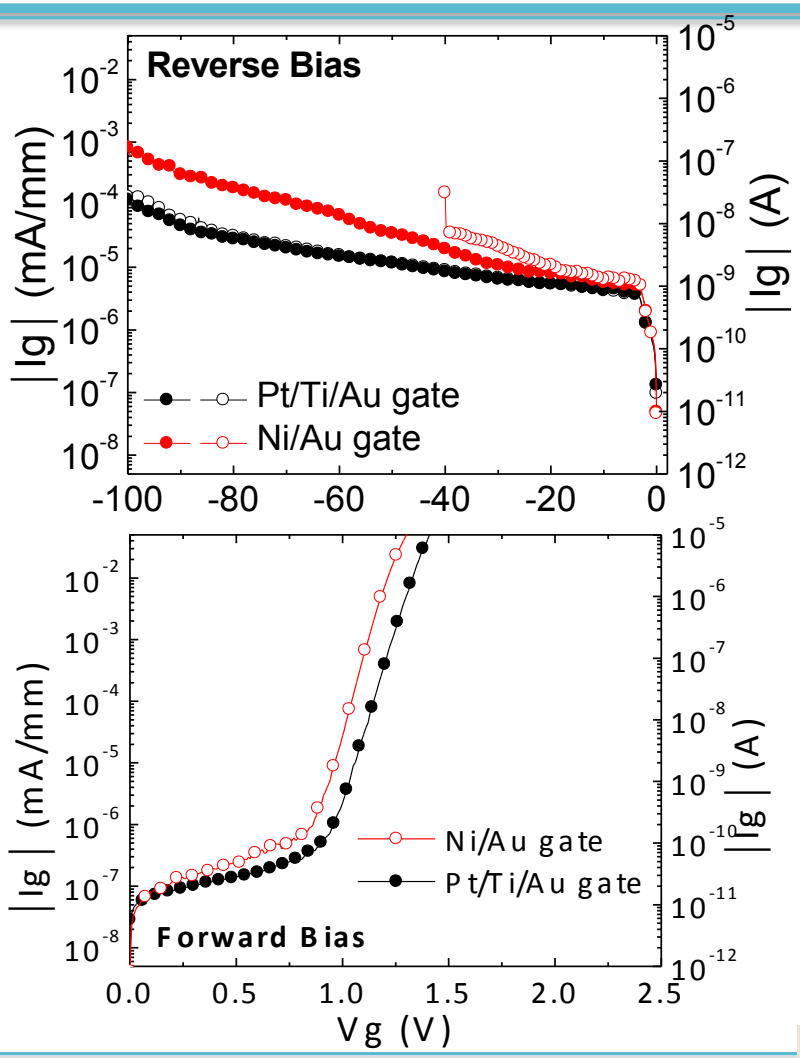


Field-plate Conclusions

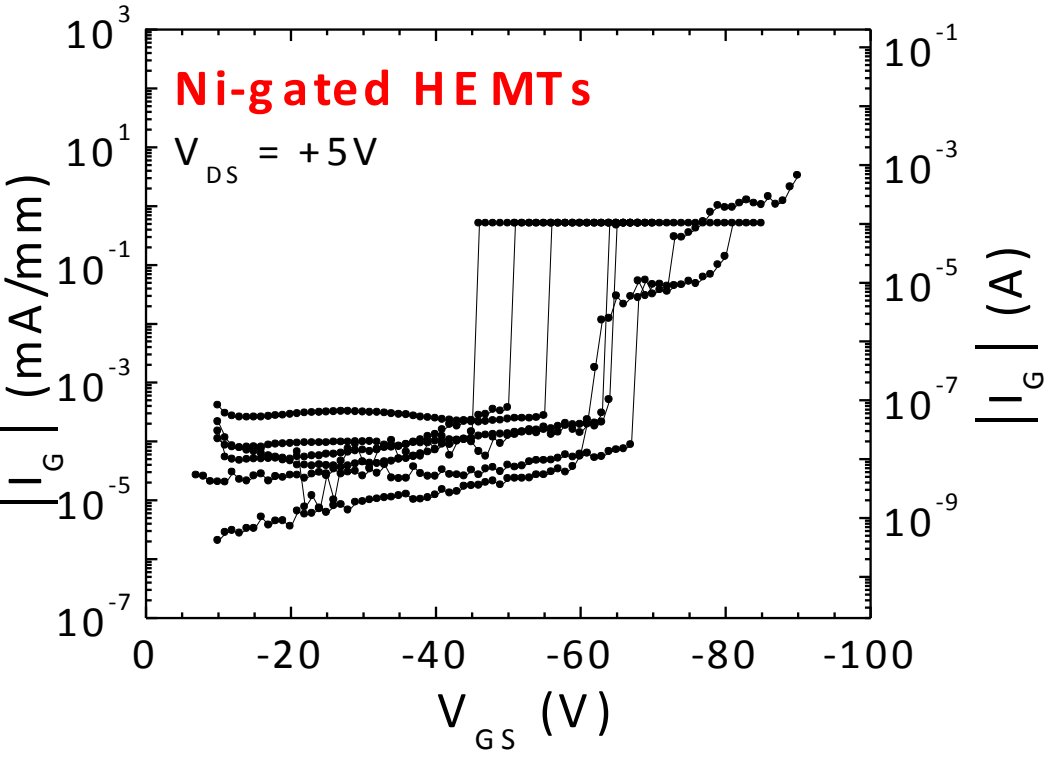
By employing Source field plate the device's critical voltage has been improved from -40 to -65V, and breakdown voltage from 50 to 150V.

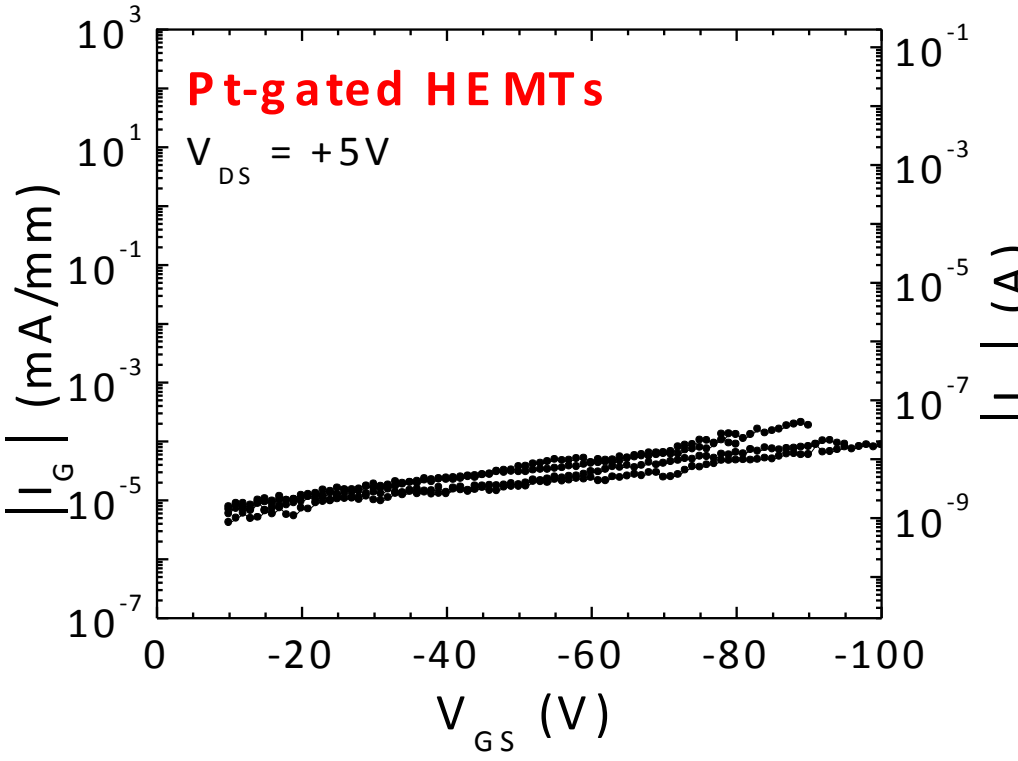
DC characteristics of Pt- and Ni-gated HEMTs



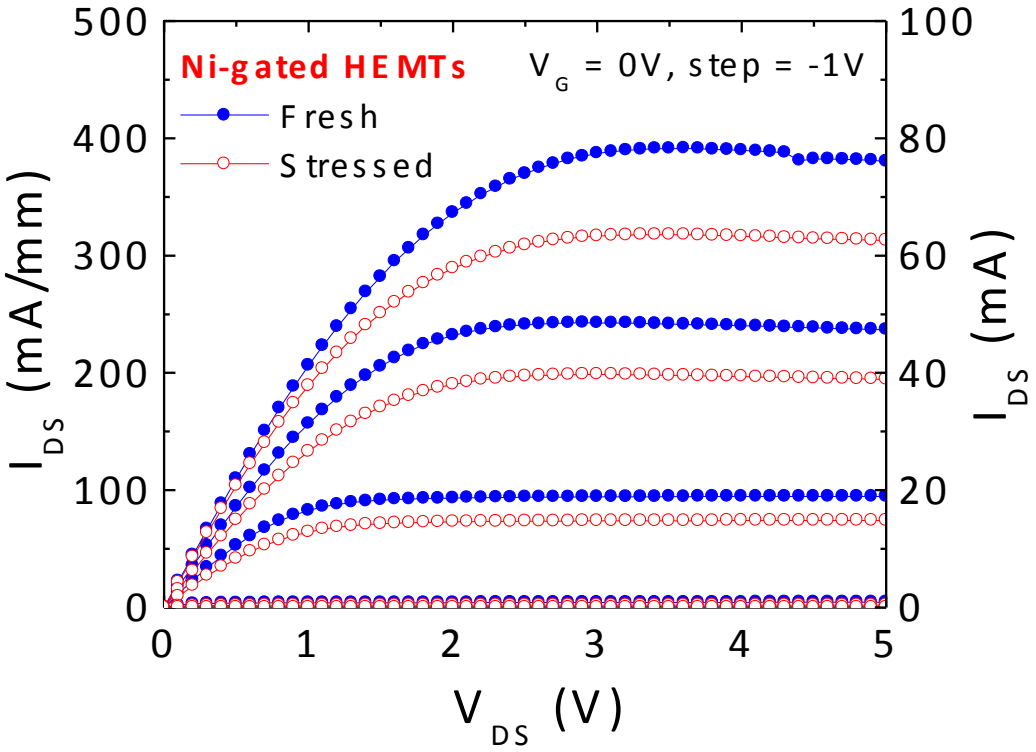


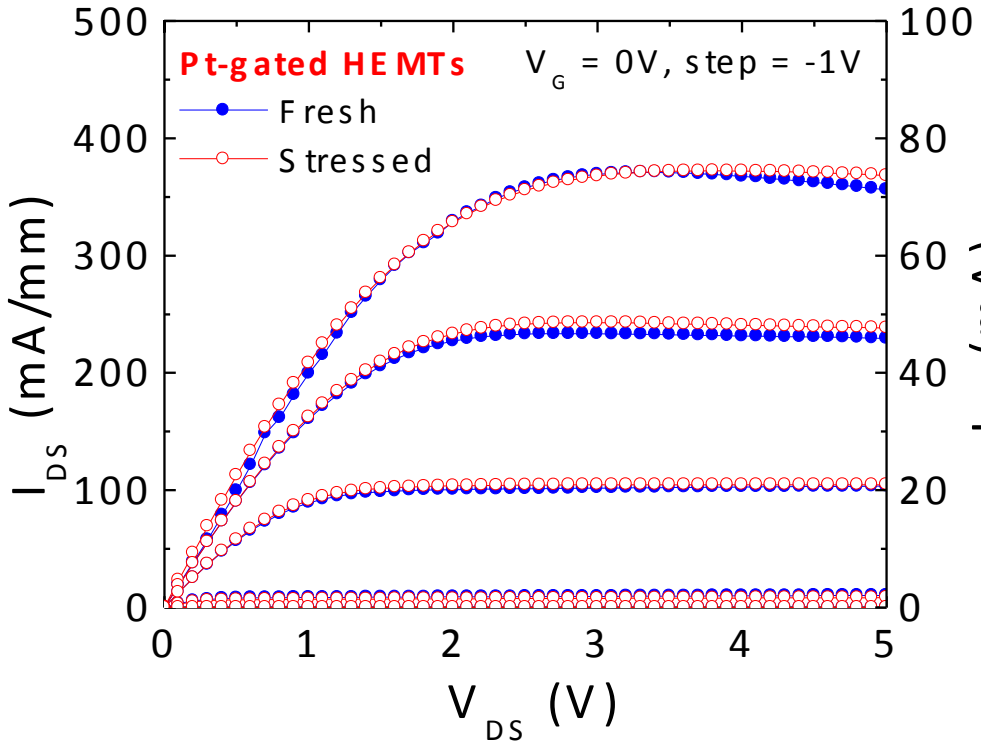
Comparison of V_{cri}



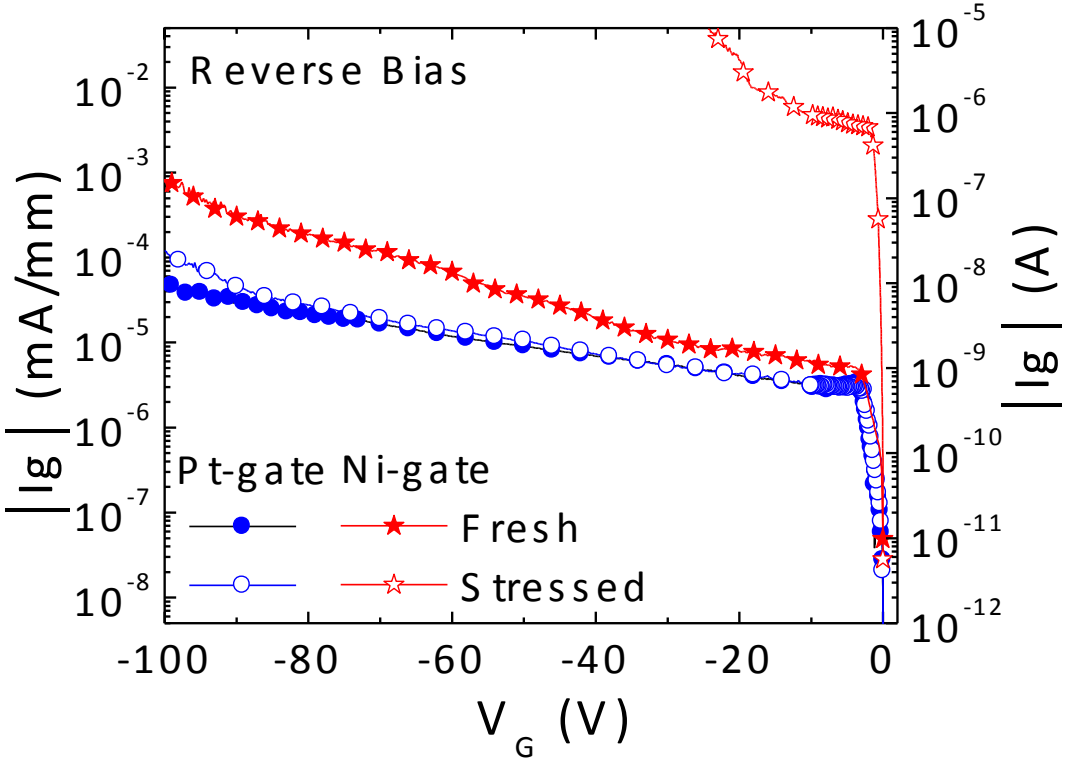


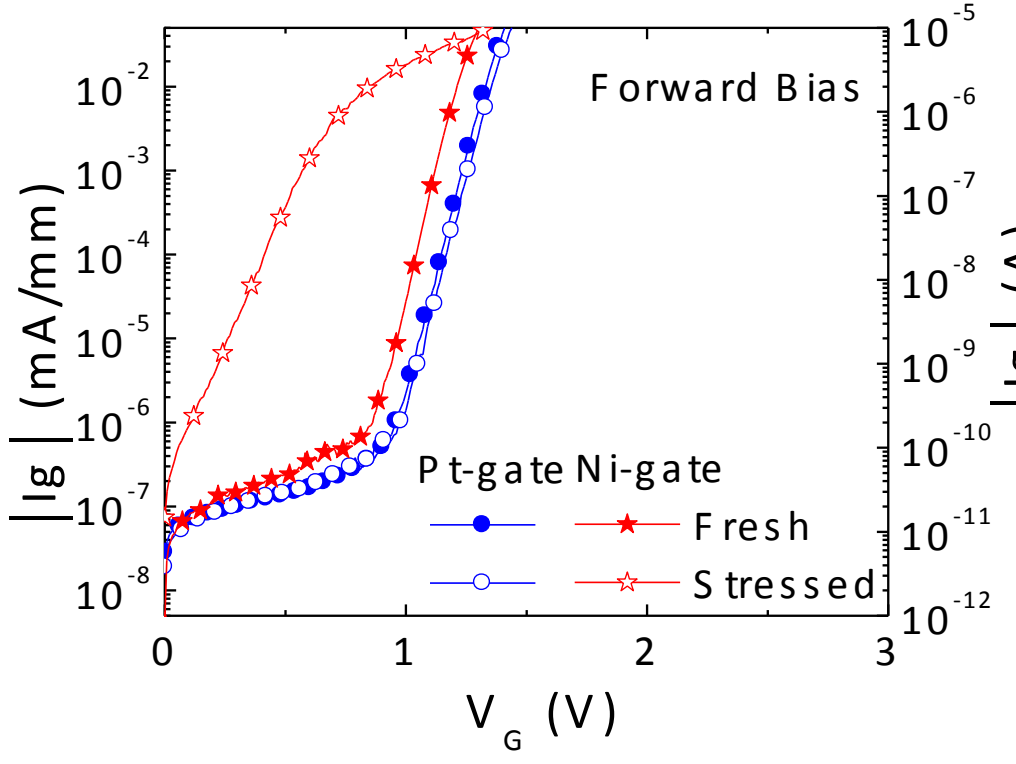
Comparison of Drain I-V



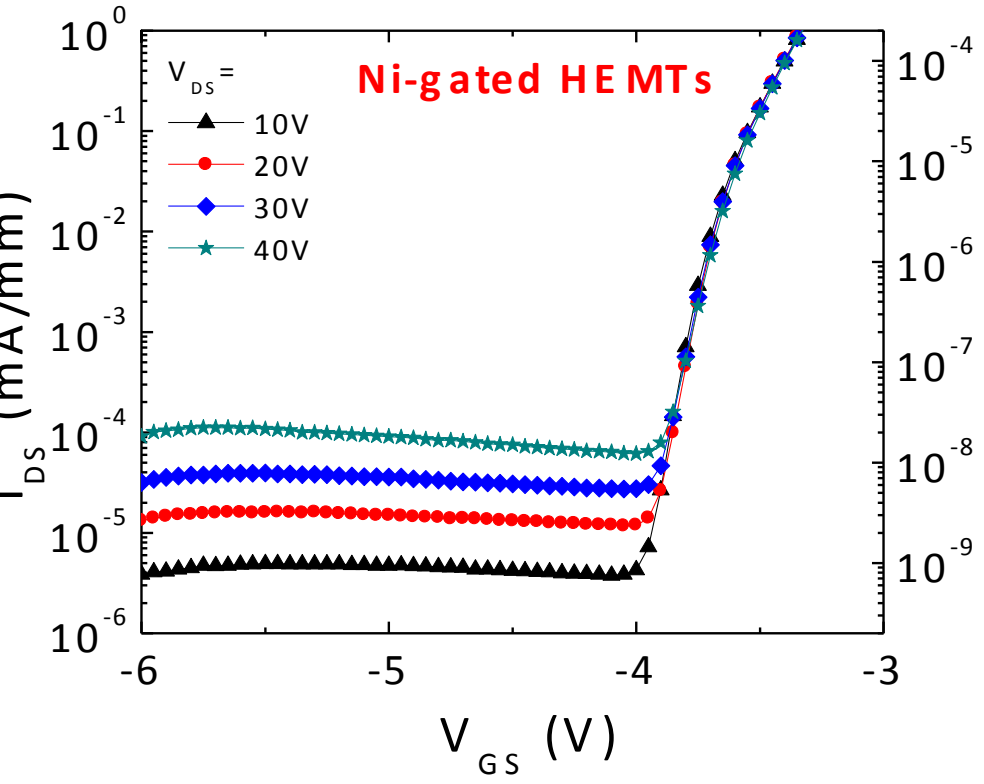


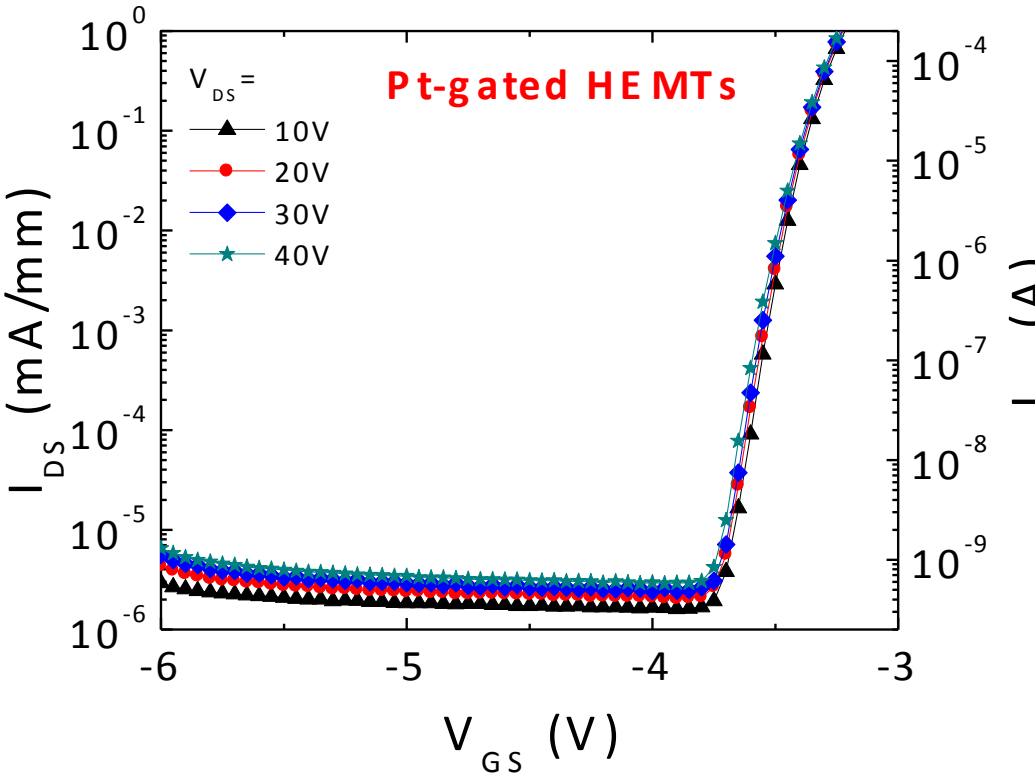
Comparison of Gate leakage current



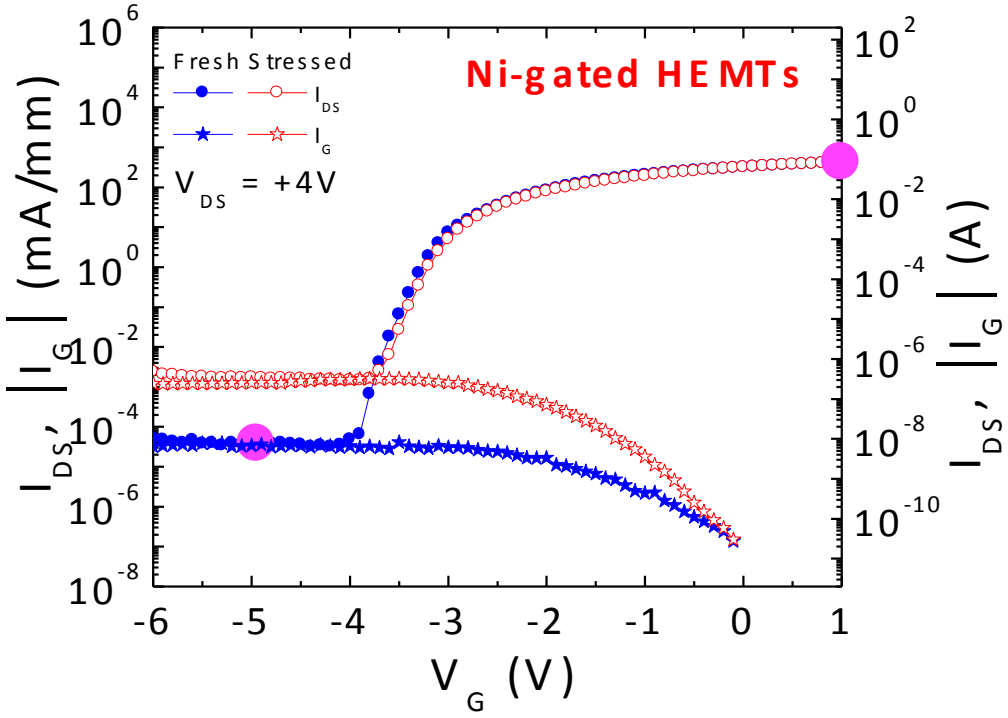


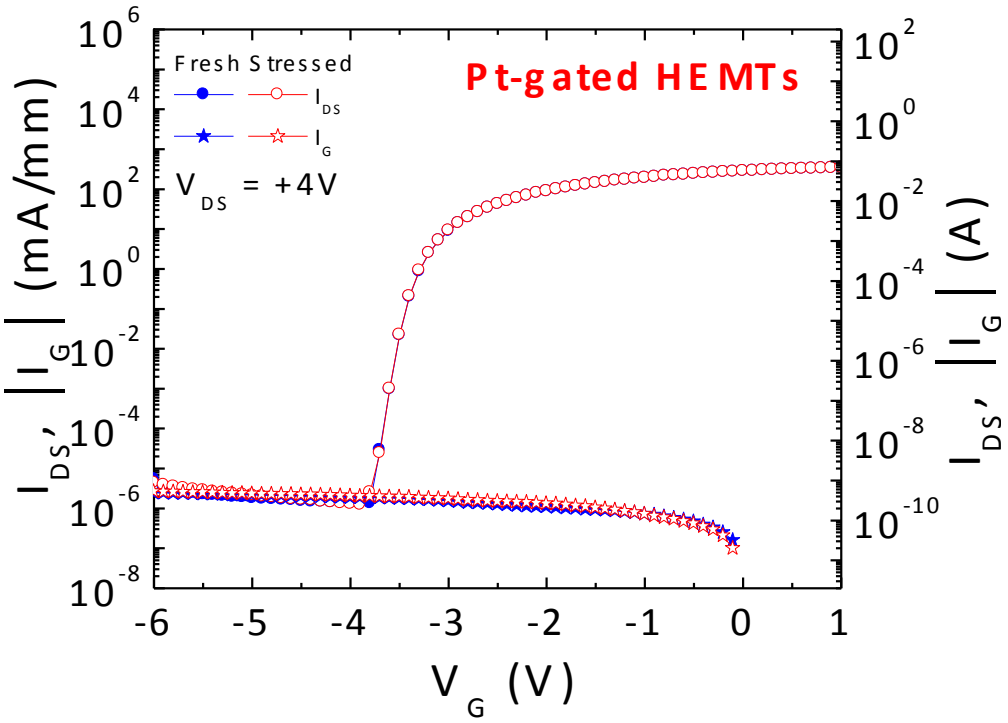
Comparison of sub-threshold leakage current





Comparison of ON/OFF ratio



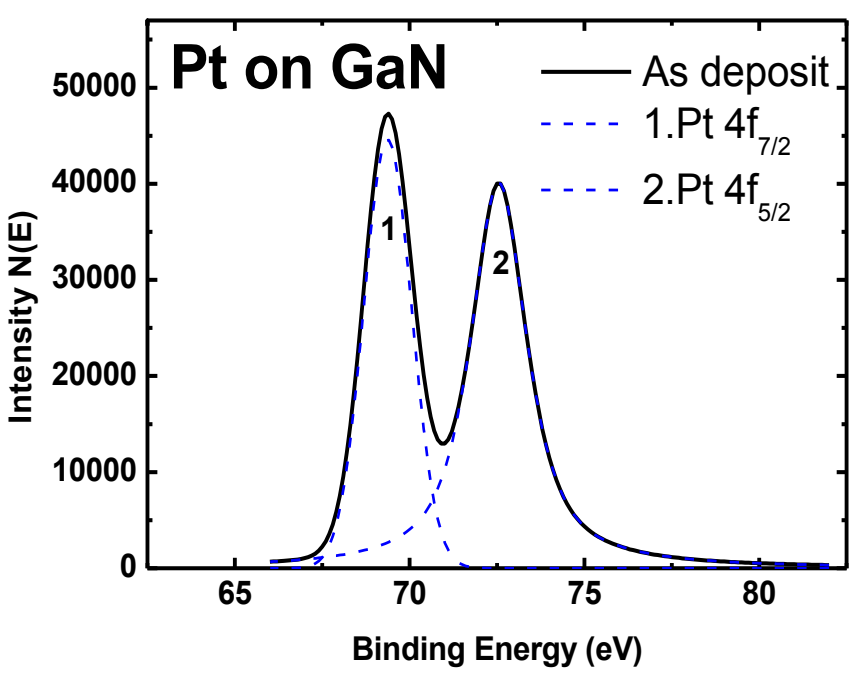


Summary of parameters before/after stress

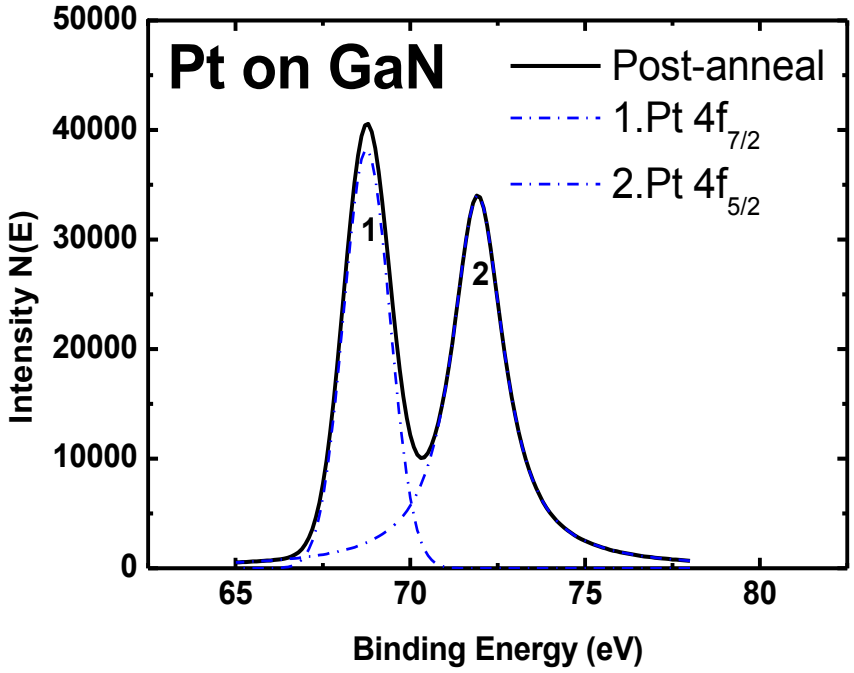
		Subthreshold slope (mV/dec)	On/Off ratio	Ideality factor	Schottky barrier height (V)
Pt/Ti/Au	Fresh	65.7	1.73×10^8	1.61	1.25
	Stressed	67.3	1.44×10^8	1.53	1.26
Ni/Au	Fresh	111.7	1.21×10^7	1.72	1.17
	Stressed	171.8	2.5×10^5	4.62	0.53

XPS results

As deposit

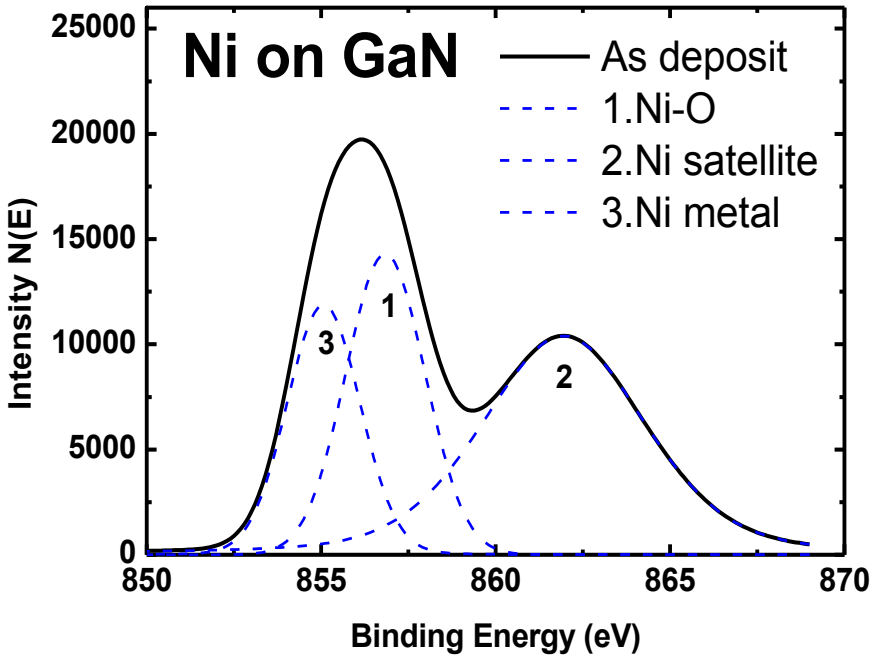


Post annealed



XPS results

As deposit



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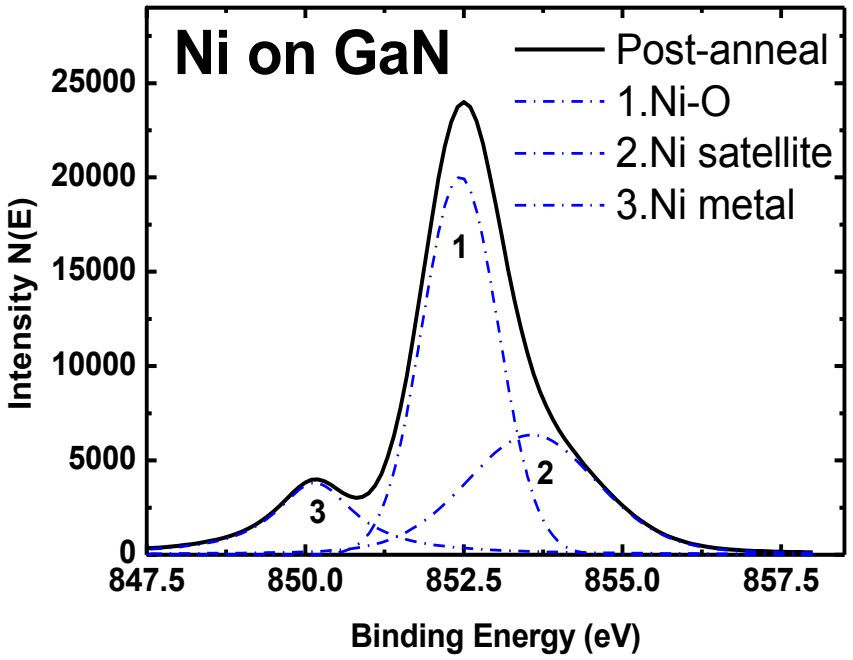
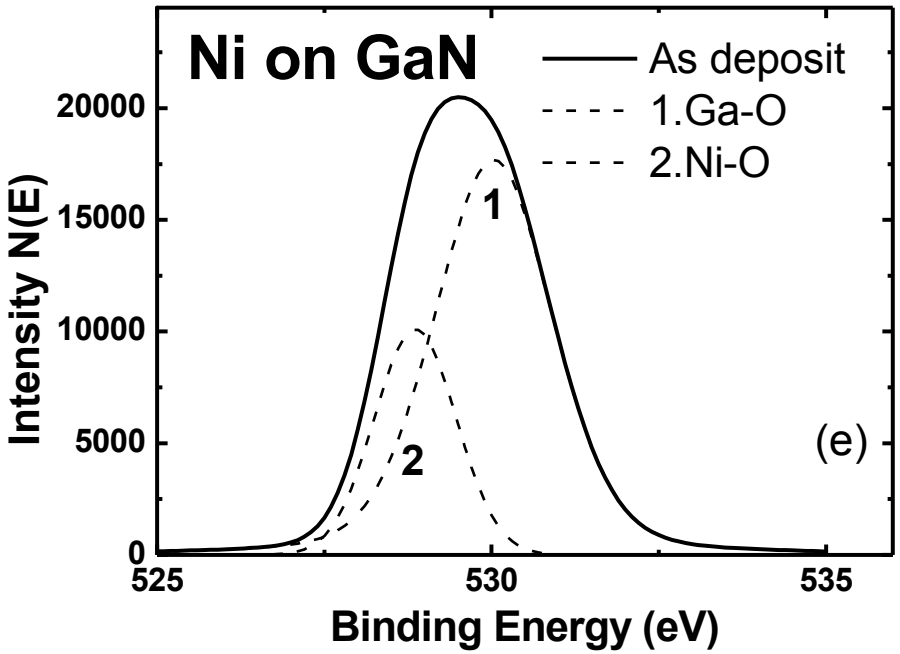


XPS results

As deposit



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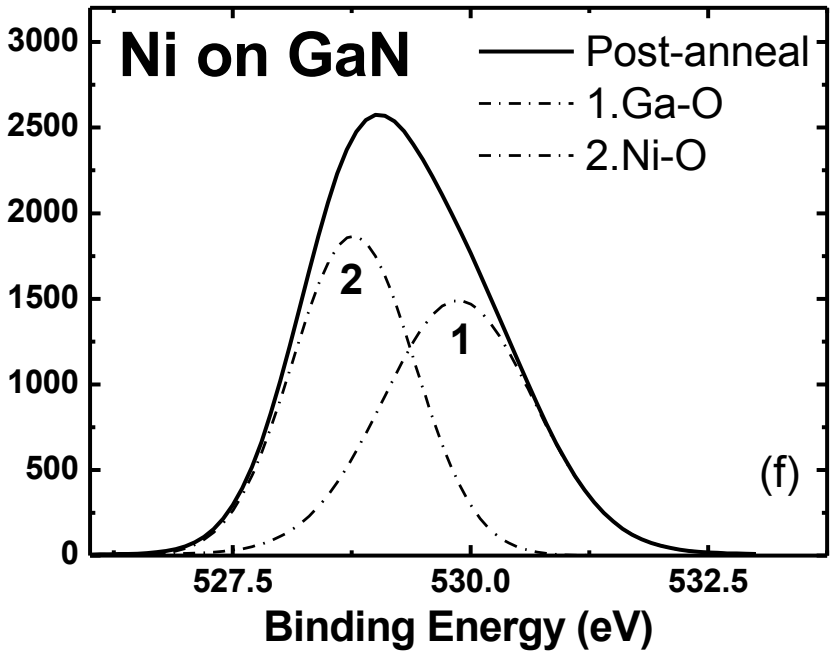

Pt gate Conclusion

Using Pt gate metallization, the critical voltage of electrical stress has been enhanced from -55V with Ni gate to greater than -100V with Pt gate. The reliability of AlGaN/GaN HEMTs have been enhanced significantly.